

November 5, 1998

TO: 301/Chairman, Advanced Land Imager (ALI) PER Team/Josef A. Wonsever
FROM: 426/EO-1 Mission Systems Engineer/Peter D. Spidaliere
Subject: Responses to EO-1 ALI PER RFAs

The EO-1 ALI PER was held at MIT/Lincoln Laboratory on August 5, 1998. The review resulted in 10 RFAs being given to the EO-1 ALI team. The ALI team's response to these RFAs is attached. All RFAs were constructive and the responses comply with the review teams request.

We thank the ALI PER review team for an excellent unbiased review of the instrument status and planned environmental testing.

Peter D. Spidaliere

SUMMARY OF ALI PER RFAs AND RESPONSES

<u>EO-1 ALI PER RFA Number</u>	<u>SPECIFIC REQUEST</u>	<u>SUMMARY RESPONSE</u>
1	Optical Test at Spacecraft Level	Test will be performed
2	Include mechanism hot/cold TV starts	Tests were performed
3	EMI/EMC test waiver required	Waiver submitted
4	TV temps and durations needed	Temps and durations provided
5	Repeat EMI/EMC test if any hardware changes are made	Flight ALI EMI/EMC test will be performed prior to s/c integration
6	Understand ALICE current spikes at high temperatures	Spikes caused by ESN circuit. No resulting operation problems. Use as is.
7	Life test mechanisms in vacuum	Mechanisms have been life tested in vacuum
8	Provide orderly shutdown of ALI	Orderly shutdown time will be provided by spacecraft
9	Measure thermal resistance from ALI components to s/c heat sink	Thermal resistance measured by test. Resistance within requirements
10	Resolve 32 mil focal plane offset	Offset resolved, caused by sign error in initial analysis

REQUEST FOR ACTION

NO. 1

Project:	NMP
Spacecraft/Observatory:	EO-1
Instrument:	ALI
Ground System:	
Subsystem:	
Launch Vehicle:	
Review:	PER
Date:	August 5, 1998

Reviewer: Oren Sheinman

Phone #: (301) 286-2295

Organization: GSFC/543

Subject Area: (Circle One) Alignment Attitude Control C&DH Calibration Communication Contamination Detectors EGSE Electrical EMI/EMC Ground System Interfaces Lubrication Mass Materials Mechanical Mechanisms MGSE Operations <u>Optics</u> Parts Post Launch Power Product Assur. Propulsion Radiation Reliability Safety Schedule Science Software <u>Systems Eng.</u> Testing Thermal	<u>SPECIFIC REQUEST:</u> Page 7, ALI Verification Matrix lists an Optic test at the spacecraft level as TBD. This should be a tested item---period.
	<u>SUPPORTING RATIONALE:</u> There would need to be major rationale for not performing a test which validates the mirrors have not shifted after shipment, acoustic, and thermal testing as well as demonstrates contamination poses no problems. This issue was raised at PDR and CDR and still seems to be open. <u>RESPONSE RFA 1:</u> The EO-1 project agrees with this RFA and has scheduled an ALI End-To-End test after environmental testing and prior to shipment to the launch site. The test is presently scheduled for the time period between 9/9/99 and 9/16/99, just prior to shipment. The test is shown on the EO-1 Integration and Test Flow Diagram in the block labeled: "Focal Plane E-T-E @ Ambient".

REQUEST FOR ACTION

NO. 2

Project:	NMP
Spacecraft/Observatory:	EO-1
Instrument:	ALI
Ground System:	
Subsystem:	
Launch Vehicle:	
Review:	PER
Date:	August 5, 1998

Reviewer: Joseph Schepis

Phone #: (301) 286-6598

Organization: GSFC/543

Subject Area: (Circle One) Alignment Attitude Control C&DH Calibration Communication Contamination Detectors EGSE Electrical EMI/EMC Ground System Interfaces Lubrication Mass Materials Mechanical <u>Mechanisms</u> MGSE Operations Optics Parts Post Launch Power Product Assur. Propulsion Radiation Reliability Safety Schedule Science Software Systems Eng. Testing Thermal	<u>SPECIFIC REQUEST:</u> Include hot/cold functional starts for operable mechanisms during flight thermal/vacuum test. <u>Added Note:</u> Will be done, delete RFA
	<u>SUPPORTING RATIONALE:</u> To fully exercise mechanisms over predicted temp range, these mechanisms essentially operate as "hot start" or "cold start" since they do not continuously operate. <u>RESPONSE RFA 2:</u> This RFA was withdrawn since mechanism tests at the qualification temperatures were planned. The mechanism tests at the hot and cold qualification temperatures were performed successfully during the Thermal Vacuum Cycle tests performed between 10/16/98 and 10/25/98.

REQUEST FOR ACTION

NO. 3 & 4

Project:	NMP
Spacecraft/Observatory:	EO-1
Instrument:	ALI
Ground System:	
Subsystem:	
Launch Vehicle:	
Review:	PER
Date:	August 5, 1998

Reviewer: K. Jenkins

Phone #: (301) 286-9750

Organization: GSFC/

Subject Area: (Circle One) Alignment Attitude Control C&DH Calibration Communication Contamination Detectors EGSE Electrical <u>EMI/EMC</u> Ground System Interfaces Lubrication Mass Materials Mechanical Mechanisms MGSE Operations Optics Parts Post Launch Power Product Assur. Propulsion Radiation Reliability Safety Schedule Science Software Systems Eng. Testing <u>Thermal</u>	<u>SPECIFIC REQUEST:</u> 1. EMI/EMC – Radiated narrow band emissions exceeded specifications. (in 5/28 Monthly). A waiver is required when an exceedence occurs. 2. Thermal – Temp and duration during thermal testing is still TBD. Prior to test at LL this should be resolved.
	<u>SUPPORTING RATIONALE:</u> 1. EMI/EMC – Project approval of exceeded specification is required. 2. Thermal – Environmental test group/thermal and project (GSFC) need to review this and approve.

RESPONSE RFA 3:

This RFA concerns the EMI/EMC test performed on the ALI instrument STM (Structural Thermal Model). When the MIL-STD-461C narrowband Radiated Emissions test (RE-02) was performed the emissions exceeded the specification at between 35 and 40 discrete frequencies between 2 and 250 MHz.

MIT/LL submitted a Waiver No. ALI-1 to obtain approval for this specification deviation. The waiver will be approved by the EO-1 project for the STM only. Changes have been made to the flight ALI to reduce these emissions. The changes include: 1. Elimination of a synchronization signal, 2. Improve grounding, 3. Add a power input filter box, 4. Install MLI. An instrument level EMI/EMC test will be performed on the flight instrument at GSFC prior to instrument/spacecraft integration.

RESPONSE RFA 4:

The signed ALI Thermal Vacuum Test Plan (AKU-S1031) includes the approved instrument mounting plate thermal cycling temperature extremes of -10 and $+40$ degrees C. and dwell times of 4 hours at each plateau. The maximum temperature of the ALICE power module baseplate was 16 degrees C above the mounting plate temperatures. The survival extremes were -30 and $+50$ degrees C and dwell time of one hour. These and all other details of the test plan were approved by GSFC prior to beginning the test. The Thermal Vacuum Cycle testing was successfully completed between 10/4/98 and 10/25/98.

REQUEST FOR ACTION

NO. 5

Project:	NMP
Spacecraft/Observatory:	EO-1
Instrument:	ALI
Ground System:	
Subsystem:	
Launch Vehicle:	
Review:	PER
Date:	August 5, 1998

Reviewer: Gary Brown

Phone #: (301) 286-1304

Organization: GSFC/

Subject Area: (Circle One) Alignment Attitude Control C&DH Calibration Communication Contamination Detectors EGSE Electrical EMI/EMC Ground System Interfaces Lubrication Mass Materials Mechanical Mechanisms MGSE Operations Optics Parts Post Launch Power Product Assur. Propulsion Radiation Reliability Safety Schedule Science Software Systems Eng. Testing Thermal	<u>SPECIFIC REQUEST:</u> Retest (EMI/EMC) if make changes. EMI/EMC tests should be repeated after changes to shielding and grounding schemes. If waivers are granted and the design does not change, then of course retest is not needed.
	<u>SUPPORTING RATIONALE:</u> Adding ground points can often create current loops that increase emissions at different frequencies than seen during initial tests. Finding out about EMI/EMC problems at the spacecraft level would be a much larger impact than re-testing the box with design modifications.

<u>RESPONSE RFA 5:</u> Changes have been made to the flight ALI to reduce the emissions that were found during the STM RE-02 test as noted in the response to RFA 4. The changes to the flight ALI include 1. Elimination of a synchronization signal, 2. Improve grounding, 3. Add a power input filter box, 4. Install MLI. An instrument level EMI/EMC test will be performed on the flight instrument at GSFC prior to instrument/spacecraft integration.

REQUEST FOR ACTION

NO. 6

Project:	NMP
Spacecraft/Observatory:	EO-1
Instrument:	ALI
Ground System:	
Subsystem:	
Launch Vehicle:	
Review:	PER
Date:	August 5, 1998

Reviewer: Gary Brown

Phone #: (301) 286-1304

Organization: GSFC/

Subject Area: (Circle One) Alignment Attitude Control C&DH Calibration Communication Contamination Detectors EGSE <u>Electrical</u> EMI/EMC Ground System Interfaces Lubrication Mass Materials Mechanical Mechanisms MGSE Operations Optics Parts Post Launch Power Product Assur. Propulsion Radiation Reliability Safety Schedule Science Software Systems Eng. Testing Thermal	<u>SPECIFIC REQUEST:</u> Understand current spikes. Be sure to <u>fully understand</u> the current spikes in the ALICE at high temperatures. If it is a function of timing between pluses or events delays on the microprocessor, design changes should be considered. In asynchronous circuits (if they exist in the design), timing margins should be measured between event pluses to guarantee against race condition and setup and hold time violations (measure for end-of-life worst case temperatures).
	<u>SUPPORTING RATIONALE:</u> In asynchronous digital designs, inherent delays (particularly through silicon devices) can change over temperature and life (perhaps radiation effects for example). If the timing margins are inadequate, changes over temperature and life could lead to repeatable failures in the digital electronics. The current spikes at the microprocessor might be an indication of potential timing problems.

RESPONSE RFA 6:

This analysis and conclusion of the investigation into this anomaly is covered in detail in MIT/Lincoln Laboratory ALI Test Anomaly Work Sheet (TAWS) No. ALICE-003. A summary of the analysis and conclusion follows.

During thermal cycling of the flight ALICE at +40 Degrees C on the 28-volt input an unexpected current waveform with a positive hump of 40 ma and a negative spike of 60 ma riding on the DC average of 700ma. The ALICE continued to operate properly. Investigation showed that this waveform was also present in the EDU (Engineering Development Unit) and results from the analog signal sampling and digitizing portion of the ALICE operation. The ESN (Essential Services Node) is the location of the cause of this anomaly since it contains the analog multiplexor and the A/D converter. Isolating this phenomenon to a particular integrated circuit would require test probing the pins of all Integrated circuits involved. Since the ALICE operated properly the circuits were not probed to avoid disassembly and possible damage. Testing up to 52 Degrees C showed that the ALICE operated properly and the waveform amplitude decreased.

Conclusion: The 28V input current waveform in the ALICE at elevated temperatures is odd, but the ALICE continues to operate properly. The anomaly was observed in the flight and EDU ALICES, so it is not being caused by an out-of-spec component in the flight ALICE. The waveform was shown to occur during analog signal sampling and digitizing, and is not due to timing problems in the digital circuitry (also, if it were a timing problem the ALICE would likely not be working properly). The waveform is deemed to be a curiosity, but not a problem. The flight ALI including the ALICE has successfully completed Thermal Vacuum Cycling with no problems. The EO-1 project plans no further investigation and to use the ALICE as is.

REQUEST FOR ACTION

NO. 7

Project:	NMP
Spacecraft/Observatory:	EO-1
Instrument:	ALI
Ground System:	
Subsystem:	
Launch Vehicle:	
Review:	PER
Date:	August 5, 1998

Reviewer: Gary Brown

Phone #: (301) 286-1304

Organization: GSFC/

<p>Subject Area: (Circle One) Alignment Attitude Control C&DH Calibration Communication Contamination Detectors EGSE Electrical EMI/EMC Ground System Interfaces <u>Lubrication</u> Mass Materials Mechanical <u>Mechanisms</u> MGSE Operations Optics Parts Post Launch Power Product Assur. Propulsion Radiation Reliability Safety Schedule Science Software Systems Eng. Testing Thermal</p>	<p><u>SPECIFIC REQUEST:</u></p> <p>Mechanisms should be life tested in a vacuum and at various temperatures during the test (over predicted operating temps).</p>
	<p><u>SUPPORTING RATIONALE:</u></p> <p>The dominant failure modes in mechanisms, rolling and sliding friction, lubricants and winding failures can be strong functions of conditions. More potential design problems could be uncovered by life testing with realistic conditions.</p> <p><u>RESPONSE RFA 7:</u></p> <p>The three ETU (Engineering Test Unit) ALI mechanisms (aperture cover, aperture selector, and diffuser plate) were successfully life tested between 9/21/98 and 10/ 5/98. The life testing was performed in a vacuum and at the predicted operating temperatures. These ETU mechanisms went through 1.5 times the number of cycles that the flight units will experience during test and on-orbit operation</p>

REQUEST FOR ACTION

NO. 8

Project:	NMP
Spacecraft/Observatory:	EO-1
Instrument:	ALI
Ground System:	
Subsystem:	
Launch Vehicle:	
Review:	PER
Date:	August 5, 1998

Reviewer: Joseph *Schepis

Phone #: (301) 286-6598

Organization: GSFC/

Subject Area: (Circle One) Alignment Attitude Control C&DH Calibration Communication Contamination Detectors EGSE Electrical EMI/EMC Ground System Interfaces Lubrication Mass Materials Mechanical Mechanisms MGSE <u>Operations</u> Optics Parts Post Launch Power Product Assur. Propulsion Radiation Reliability Safety Schedule Science <u>Software</u> Systems Eng. Testing Thermal	<u>SPECIFIC REQUEST:</u> Verify/compare time required for orderly shutdown versus allowable time from spacecraft. Assess ramifications of doors/calibrators partially closed/stowed on power off. What state does ALICE boot into when mechanisms were moving at power off?
	<u>SUPPORTING RATIONALE:</u> If spacecraft can provide the required time, close doors and stow calibrator, etc, to fully safe the instrument. <u>RESPONSE RFA 8:</u> Details of the commands required to be sent to ALI prior to power off are shown in the two lists in the MIT/LL ALI response on the next page. The first list requires 40 seconds to complete. The first four commands of the second list require less than 20 seconds to complete. ALI is then in the proper state to be turned off. The spacecraft will provide a minimum of 120 seconds (margin of 60 seconds) from beginning ALI turn off command sequence until power is removed.

RESPONSE RFA 8 (ALI DETAILS):

EO-1 PER Request for Action No. 8

There may be several actions undertaken by the spacecraft that require that the status of the ALI be considered before initiation. One action that clearly falls into this category, and is addressed in this note, is reducing and/or shutting off electrical power.

Before any change in power is undertaken, a command script should be exercised that will deliver ALI into a safe status by stowing all mechanisms. This will require issuing six commands starting at time T_0 (seconds):

T_0 :	Enable Mechanism Power
$T_0 + \epsilon$:	Close Cover
$T_0 + 15$:	Enable Mechanism Power
$T_0 + 15 + \epsilon$:	Stow Aperture Shutter
$T_0 + 30$:	Enable Mechanism Power
$T_0 + 30 + \epsilon$:	Stow Calibration Diffuser
$\sim T_0 + 40$:	Done

After execution of this script, ALI is in a safe status for power reduction (and for any abnormal spacecraft maneuvering). The following power reduction steps can then be sequentially commanded:

1) Turn off floodlamps.	
2) Turn off FPE Operational Power	$\Delta\text{power} = \text{TBD}$
3) Turn off FPE Thermal Power	$\Delta\text{power} = \text{TBD}$
4) Disable ALICE thermal control	$\Delta\text{power} = \text{TBD}$
5) Turn off ALICE	$\Delta\text{power} = \text{TBD}$

The actual power reduction for each of these steps will be verified during testing. Generally, turning off FPE operational power has no impact on the readiness of ALI to proceed with further data collection. Turning off the FPE thermal power may cause the FPA to drift from its nominal temperature. Disabling the ALICE thermal control eliminates control of the metering truss temperatures. Finally, turning off ALICE puts the entire ALI in a non-operative state such that it depends on spacecraft survival heaters for temperature control. Time required for recovery and re-start from commands 3)-to-5) become increasingly significant.

Turning off the ALICE should only be done under the direst emergency circumstances. However, it should, without fail, be done prior to a deliberate spacecraft power shut-off.

W. E. Bicknell
L. Bernotas

REQUEST FOR ACTION

NO. 9

Project:	NMP
Spacecraft/Observatory:	EO-1
Instrument:	ALI
Ground System:	
Subsystem:	
Launch Vehicle:	
Review:	PER
Date:	August 5, 1998

Reviewer: Lou Fantano

Phone #: (301) 286-9965

Organization: GSFC/

<p>Subject Area: (Circle One)</p> <p>Alignment Attitude Control C&DH Calibration Communication Contamination Detectors EGSE Electrical EMI/EMC Ground System Interfaces Lubrication Mass Materials Mechanical Mechanisms MGSE Operations Optics Parts Post Launch Power Product Assur. Propulsion Radiation Reliability Safety Schedule Science Software Systems Eng. Testing <u>Thermal</u></p>	<p><u>SPECIFIC REQUEST:</u></p> <p>Establish by test the thermal resistance from ALI and heat dissipating components, through the chassis walls to the spacecraft heat sink interface. Based on test results and spacecraft interface temperature extremes, re-establish ALI box thermal qualification levels.</p> <p><u>SUPPORTING RATIONALE:</u></p> <p>The ALI thermal design was originally configured to transport electronics dissipated heat to a local radiator. The radiator has been eliminated. The new heat transfer path is through the thin wall box chassis. This will have a significant effect on ALI box predicted on orbit temperatures.</p> <p><u>RESPONSE RFA 9:</u></p> <p>The thermal resistance from ALI power module heat sink to the to the simulated spacecraft deck was measured in a vacuum bell jar with the ALICE mounted in the flight configuration and covered with flight like MLI. The temperature increase from the deck to the power module converters heat sink (maximum temperature external to components) was measured and found to be 16 Degrees C. at the maximum total box power dissipation of 28.3 W. The ALI thermal model resistances resulting from this test are tabulated in the attached thermal model email. These results were used successfully in the ALI Thermal Vacuum Cycling test. With the simulated spacecraft deck at +40 Degrees C (hot qualification) the power module heat sink reached +56 Degrees C. The test temperature was within the derated limits of the components.</p>
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RESPONSE RFA 9 (Attachement):

To: nteti@swales.com,michael.k.choi.1@gsfc.nasa.gov

Subject: Latest ALICE Thermal Model

Cc: peter.d.spidaliere.1@gsfc.nasa.gov,bruce@ll.mit.edu,sforman@ll.mit.edu,leona
s@ll.mit.edu,much@ll.mit.edu,digenis@ll.mit.edu,bicknell@ll.mit.eduLeeEuiIn,
Efromson Ron

Nick and Mike,

The ALICE thermal model has been updated based on the results of the thermal resistance tests on the ALICE EDU. The new information reflects the case where the box is entirely covered with MLI and thermally coupled to the pallet through a special adaptor that will be part of the ALICE assembly. Resistors and latest power dissipation are given below.

Node i	Node J	R(°C/W)
712	713	3.58
712	714	3.58
712	715	3.86
712	716	2.22
711	713	3.58
711	714	3.58
711	715	3.86
711	716	2.22
713	715	2.20
713	716	1.49
714	715	2.20
714	716	1.49
713	714	2.00
714	115	3.88
714	116	3.88
714	121	3.88
714	122	3.88
716	116	1.90
716	122	1.90

Power dissipation is 24.81 W constant plus an additional 3.53 W for 10 minutes. The maximum total power is therefore 28.34 W for 10 minutes. Power is divided into four nodes as shown below.

Node	Power Dissipation (W)	
	Constant	10 Minutes
713	4.36	4.36
714	4.36	4.36
716	16.09	19.62

The adapter was successful in reducing the temperature excess by about a factor of 2

Dave Nathanson

REQUEST FOR ACTION

NO. 10

Project:	NMP
Spacecraft/Observatory:	EO-1
Instrument:	ALI
Ground System:	
Subsystem:	
Launch Vehicle:	
Review:	PER
Date:	August 5, 1998

Reviewer: E. Waluschka

Phone #: (301) 286-2616

Organization: GSFC/

Subject Area: (Circle One) Alignment Attitude Control C&DH Calibration Communication Contamination Detectors EGSE Electrical EMI/EMC Ground System Interfaces Lubrication Mass Materials Mechanical Mechanisms MGSE Operations <u>Optics</u> Parts Post Launch Power Product Assur. Propulsion Radiation Reliability Safety Schedule Science Software Systems Eng. Testing Thermal	<u>SPECIFIC REQUEST:</u> Resolve the 32 mil focal plane offset.
	<u>SUPPORTING RATIONALE:</u> If it's a real hardware error, this could involve disassembly, which means that retesting would be redone <u>RESPONSE RFA 10:</u> The 32 mil focal plane offset was found to be due to the incorrect sign of the Laser Unequal Path Interferometer's (LPIU) residual focus error used in the analysis. An independent focus measurement using a theodolite found no error. Details of the 32-mill focus error are discussed in the attached response from MIT/LL.

RESPONSE RFA 10 (DETAILS):

EO-1 PER Request for Action No. 10

The unexpected 32 mil required adjustment in shim thickness during alignment of the Focal Plane Assembly (FPA) to the focus of the telescope has been examined both experimentally and analytically.

Analytical:

The expected shim thickness adjustment resulted from an analysis using information supplied by SSG Inc. for the plane of best focus with respect to a coordinate system based on the telescope mounting pad locations. Three staff members independently reviewed the analysis and concluded it was correct, using the information given.

It was discovered upon visiting SSG Inc. to discuss this Action, that the sign of the Laser Unequal Path Interferometer's (LUPI's) residual focus error had not been independently measured during SSG Inc.'s testing at MIT/LL. (The testing took place after the telescope and the metering truss assembly had been dis-assembled, cleaned, and then re-assembled.) Rather, the sign of the residual focus error was taken to be the same as that determined at SSG Inc. for the previously assembled telescope and metering truss.

It was agreed that the possibility that the sign of the focus error was opposite to that of the previously assembled telescope and metering truss was a very realistic one. The results of such a sign reversal is to reverse the piston distance and pitch and roll angles of the FPA best focus with respect to a coordinate system based on the telescope pad positions. The analysis was again independently reviewed by the three staff members and a universal conclusion resulted: Reversal of the sign error reported by SSG Inc. would have given an expected shim thickness that was equal to the actual, final shim thickness to within the +/- 3 mil telescope depth-of-focus.

Experimental:

During retest of focus after vibration the focal plane was viewed through a collimated theodolite (Zeiss ETh 2). The detectors appeared in focus. This independent focus test had a resolution of +/- 11 mils, which was sufficient to ascertain a 32-mil error.

Conclusion:

The collimator used for determining focus was, itself, checked during the procedure using two independent methods: a shear plate and a LUPI interferometer. An independent check for a 32-mil error was conducted using a theodolite and no such error was found. A very plausible explanation of the unexpected 32-mil shim thickness adjustment was discovered to be that of an incorrect sign of the re-assembled telescope's residual focus error reported by SSG Inc.

W. E. Bicknell
21 September 1998